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(54) Title: DIFFRACTIVE STRUCTURE

(57) Abstract

A diffractive structure (100) has a substantially planar substrate (1). A set of facets (2) is formed in or on said substrate (1), the plane or planes in which the facets (2) lie being arranged at a non-zero angle to the plane of the substrate (1). Each facet (2) has a diffraction grating (5) formed thereon. The diffractive structure (100) will produce colour over a wide range of viewing and illumination angles.

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DIFFRACTIVE STRUCTURE

The present invention relates to a diffractive structure.

5　　　In many applications, it is desirable to have a diffractive structure having reflective properties which do not depend upon specific limited illumination and viewing angles to produce colour.

For example, in security films, security holograms
10　conventionally consist of a thermoformed plastic layer having a reflective aluminium film deposited on the thermoformed layer. The hologram is formed by surface relief. The absence of any absorption within the structure, and the angular sensitivity of a holographic
15　image, means that under diffuse illumination (such as dull daylight or rooms lit by many lamps), the hologram cannot be seen or can only be seen from within a very narrow range of viewing angles.

As a further example, diffractive pigments, such as
20　those disclosed in JP-A-63/172779, would benefit from the use of a diffractive structure which does not appear "washed out" and lacking in colour under normal outdoor viewing conditions. JP-A-63/172779 discloses a pigment which consists of a multiplicity of particles each of which
25　carries on its surface grooves that form a diffraction grating. Since the gratings on the particles suffer strong angular dependence and have no intrinsic absorption, the diffractive colour effect will only be visible under strong, highly directional, illumination such as direct
30　sunshine or spotlight illumination. Under diffuse illumination (for example on an overcast day), the pigment as disclosed in JP-A-63/172779 would appear grey.

An object of the present invention is to provide a diffractive structure that will produce colour over a wide
35　range of viewing and illumination angles.

According to a first aspect of the present invention, there is provided a diffractive structure, the structure comprising: a substantially planar substrate; and, a set of facets formed in or on said substrate, the plane or
5   planes in which the facets lie being arranged at a non-zero angle to the plane of the substrate; the facets having a diffraction grating formed thereon.

According to a second aspect of the present invention, there is provided a diffractive structure, the structure
10   comprising: a first row of facets which lie in substantially the same first plane; and, a second row of facets which lie in substantially the same second plane, the second plane being at an angle between 0° and 180° to the first plane such that the first row of facets and the
15   second row of facets oppose each other; each facet having formed thereon a diffraction grating.

According to a third aspect of the present invention, there is provided a method of manufacturing a diffractive structure as described above, the method comprising the
20   steps of: (A) producing a mould by machining a substrate with repeated passes of a cutting tool, the tool cutting the substrate deeper on each pass of the tool thereby to produce a cut face having machining lines; (B) repeating step (A) to cut a further similar lined face opposite said
25   first face thereby to produce a groove having machining lines on each opposed face; (C) producing a master from said mould; and, (D) producing the diffractive structure from said master, each facet having formed thereon a diffraction grating corresponding to the machining lines of
30   the grooves in the mould.

According to a fourth aspect of the present invention, there is provided a method of manufacturing a diffractive structure as described above, the method comprising the steps of: (A) producing a mould by anisotropic etching in
35   a silicon substrate to produce a plurality of facets on the mould; (B) coating the mould with a resist layer; (C)

writing the fine structure of the diffraction grating
directly into the resist with an electron beam or an ion
beam; (D) producing a master from said mould; and, (E)
producing the diffractive structure from said master.

5   Preferred features of the present invention are set
out in the claims below.

         Thus, in an example of the invention, a prismatic
surface structure consisting of an array of substantially
planar facets is formed in a polymer layer. These facets
10   are typically in the region of 1 micron to 100 microns
across and are disposed at a predetermined angle to the
plane of the polymer layer. A grooved surface, a ruled
array of tetrahedra, square pyramids or a corner cube
structure (in which the facets are all squares) are
15   examples of such a prismatic structure. A diffraction
structure is formed on the surface of each facet. This
smaller structure may be (but is not restricted to) an
array of grooves, a crossed grating or a 2-dimensional
array of pits and peaks such as the known "motheye"
20   structure. The smaller structure will have typical
dimensions ranging from half the facet size down to 0.1
micron. This structure is preferentially metallised such
that it is absorbing at some angles of incidence but
produces strong diffraction at other angles.

25   The invention provides a diffractive structure that
will produce colour over a wide range of viewing and
illumination angles. The diffractive structure can be
manufactured in a simple manner using conventional film-
forming plastics.

30   Embodiments of the present invention will now be
described by way of example with reference to the
accompanying drawings, in which:

         Fig. 1 is a schematic perspective view of an example
of a diffractive structure according to the present
35   invention;

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Fig. 2 is a schematic perspective view of another example of a diffractive structure according to the present invention;

Fig. 3 is a schematic perspective view of a further example of a diffractive structure according to the present invention;

Fig. 4 is a schematic cross-sectional view through a polymer-filled diffractive structure;

Fig. 5 is a drawing showing a representation of a light ray incident on the diffractive structure;

Fig. 6 shows the distribution of light rays incident on the surface of a polymer layer of the diffractive structure;

Fig. 7 shows the distribution of light rays incident within the polymer layer of the diffractive structure;

Fig. 8 shows the distribution of light rays incident on the grating of the diffractive structure;

Fig. 9 shows the distribution of light rays diffracted from the grating of the diffractive structure;

Fig. 10 shows the distribution of light rays leaving the diffractive structure; and,

Fig. 11 is a CIE (Commission International de l'Eclairage) colour chart showing how the perceived colour varies with viewing angle.

In Figure 1, there is shown a diffractive structure 100 formed by a substrate 1 having an array of facets 2. The facets 2 in this example are provided by the triangular faces 2 of an array of square-base pyramids 3. The pyramids 3 are formed in or on the substrate 1 with their square bases 4 in the same plane so as to provide respective rows of coplanar facets 2. The length of each side of the square bases 4 of the pyramids 3 may be in the range 1μm to 100μm. Each facet 2 of the pyramids 3 has upon it a diffraction structure such as a ruled diffraction grating 5 formed by grooves or lines 6 having a regular spacing therebetween. The diffraction grating 5 in this

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example has a period of 300nm (i.e. the spacing between successive lines 6 is 300nm) with a height (i.e. the depth of the lines 6) of about 100nm.

Instead of square-base pyramids 3, the two-dimensional
5   facets 2 can be formed as the faces of triangular-base pyramids, regular tetrahedra (see Figure 2), a corner cube structure (in which all or substantially all of the facets are squares), or any other polyhedra or structures which provide an array of identical or substantially similar
10   facets which project out of the plane of the substrate 1 at an angle between 0° and 90° to the plane of the substrate 1.

Instead of a lined diffraction grating as described above, a 2-dimensional array of pits and peaks such as the
15   known "motheye" structure shown in Figure 3 may be used as the diffraction grating 5.

Generally speaking, the length of the bases of the facets 2 may be in the range 1μm to 100μm. The pitch of the diffraction grating 5 formed on a facet 2 may be in the
20   range of 0.1μm up to about one half of the length of the bases of the facets 2. Thus, for example, where a facet 2 has a base length of 1μm, the pitch of the diffraction grating 5 may be 0.1μm to 0.5μm. Where a facet 2 has a base length of 100μm, the pitch of the diffraction grating
25   5 may be 0.1μm to 50μm.

Because the diffraction grating structure 5 is at an angle to the normal to the substrate 1, sub-wavelength diffraction gratings can be used, thus providing minimum dispersion (i.e. as little colour variation with angle as
30   possible) and cut off of some colours which cannot be reflected because their wavelength is too long.

Furthermore, opposing facets 2 allow short wavelength colours to be trapped because they are diffracted at a higher angle with respect to the facets than the longer
35   wavelengths.

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Thus, in the preferred embodiment, there are two
mechanisms for colour selection. Dazzling colour effects
can be produced even under diffuse lighting and without the
use of pigments or dyes.

5   Two-dimensional facet structures as described, such as
the faces of arrays of pyramids or tetrahedra, reduce the
sensitivity of the diffractive structure 100 to rotation of
the structure 100 both in its own plane and out of its
plane that would be seen in a one-dimensional facet

10   structure. Thus, as will be explained further below, the
diffractive structure 100 of the present invention will
produce colour images under a wide range of lighting
conditions and viewing angles.

Using a V-groove (i.e. one-dimensional) structure for

15   the facets 2 means that the colour effect will depend on
the angle of rotation of the substrate in its plane though
relative insensitivity of the structure to rotation out of
its plane is still retained.

An example of a manufacturing process for producing

20   the diffractive structure 100 of the present invention will
now be described.

Firstly, a non-ferrous material such as brass or
copper is machined using a very sharp diamond tool (not
shown) to form a mould 100' which is substantially

25 - identical to the diffractive structure 100 to be finally
produced. The diamond tip of the tool may have an included
angle of 30°. The tool is used to cut a groove to a first
depth to provide a cut face having a length equal to the
pitch of the diffraction grating 5' to be formed. The tool

30   is then used to cut the groove to a second depth to cut the
face to a length which is twice the pitch of the
diffraction grating 5'. This process is repeated until the
groove has been cut to the desired depth, the tool being
moved deeper into the mould material by a distance such

35   that the face which is cut is cut by a length which is
equal to the pitch of the diffraction grating 5' to be

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formed on each successive pass of the tool. As a result of
these successively deeper passes of the machining tool, the
structure of the diffraction grating 5' composed of the
lines 6' is formed from natural machining marks formed
5   during the successive passes of the tool. The groove thus
cut will provide a first row of facets 2' in the material.
The opposite row of facets 2' and other rows of facets 2',
both parallel and orthogonal to the first row of facets 2',
are then produced by machining further grooves in a similar
10   manner, the further grooves being parallel and
perpendicular to the first groove. The included angle of
opposed facets 2' may be 90° for example, though this will
depend on the geometry and height of the pyramids 3,
tetrahedra or other polyhedra which provide the facets 2.

15   For speed of manufacture, a series of similar cutting
tools can be used to cut parallel rows of grooves to
provide facets 2' in a gang fashion. Orthogonal rows can
be cut by moving the same or another gang of cutting tools
perpendicularly to the first row of facets 2'.

20   An alternative technique for forming the mould 100' is
as follows. The mould 100' having the array 3 of square-
base pyramids, triangular-base pyramids, regular
tetrahedra, corner cube structure, or other polyhedra or
structure, is formed by anisotropic etching in silicon.
25   This provides very flat faces to the facets 2. The mould
is then coated with a resist layer. The fine structure
which makes up the diffraction grating 5 is then directly
written into the resist with an electron beam or an ion
beam.

30   Whichever way the mould 100' is formed, the mould 100'
is then electroformed to form a hard master 100", which is
a negative of the mould 100' and therefore also a negative
of the diffractive structure 100 to be produced. The
material of the master 100" needs to be hard enough to
35   allow embossing of a plastics material or other material

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from which the diffractive structure 100 is formed. The
master 100" may be nickel or copper for example.

:   The master 100" is then thermoformed to produce a
negative replica of the master 100" in a polymer, in the
5   same way as a conventional commercial hologram. Suitable
polymers include polymethyl methacrylate or polycarbonate.
The facets 2 on the replica are then metallised with a thin
layer of a metal such as chrome, copper, nickel or
aluminium to produce the diffractive structure 100 of
10   Figure 1. The metallised layer may be 10 to 50nm thick and
is preferably discontinuous over the small scale relief
that forms the diffraction grating 5 so that the
diffraction grating 5 is partially absorbing or
transmitting, and is only weakly specularly reflective.
15   The structure 100 is preferably then filled with a
layer of material 7. The material of the layer 7 is
transparent and may be a solvent-drying or chemically-
curing polymer, such that the structure 100 has
substantially flat and parallel outer surfaces, and the
20   internal structure relief is filled with polymer 7, as
shown in Figure 2. The polymer layer 7 may conveniently be
the adhesive which is used to fix the diffractive structure
1 to a substrate on which it is mounted.
         Light entering the polymer layer 7 is diffracted,
25   absorbed, or reflected by the facets 2. Undiffracted light
is either absorbed by the diffraction grating 5 or is
specularly reflected. If it is specularly reflected, it
passes to the neighbouring facet 2 where again it is
absorbed or specularly reflected. If the diffraction
30   grating 5 is designed such that only 10% of light falling
upon it can be specularly reflected, only 1% may re-emerge
after two such reflections. In the absence of diffraction,
the whole structure 100 is therefore substantially non-
reflective and appears to the viewer to be black. The
35   diffraction grating 5 can be designed to reduce the amount
of light which is specularly reflected by ensuring that the

pitch of the grating is less than the wavelength of light
incident on the grating and having the depth of the grating
5 such that the back reflection is cancelled by
interference. If the surface of the grating 5 is coated as
5   suggested above with a "lossy" metal (i.e. one with a low
reflectivity such as copper, nickel or aluminium) or the
metal is discontinuous across the lines 6 of the grating 5,
then the incident light is absorbed rather than reflected.

Diffraction will occur when the wavelength of incident
10   light, the angle of incidence of the light, and the period
of the diffraction grating 5 have the following
relationship:

$$\lambda/\eta = d.\sin(\varphi) + d.\sin(\theta)$$

where λ is the wavelength of the light, η is the refractive
15   index of the polymer 7 filling the diffraction structure, φ
and θ are the angles of incidence and diffraction, relative
to the normal 8 to the facet 2, respectively, and d is the
period of the diffraction grating 5, as shown in Figure 5.

The perceived colour of the structure 100 can be
20   calculated by tracing the paths of the rays which enter and
leave the structure 100 by diffraction. Figures 4 to 8
show how the distribution of rays changes as the rays are
first refracted at the polymer surface as they enter the
polymer, then diffracted at the facet, and refracted again
25   as the rays leave the polymer.

Figure 4 shows a polar plot of the intensity incident
on a surface under diffuse illumination, the surface in
this case being the outer surface of the polymer layer 7.
The intensity drops off with the cosine of the angle of
30   incidence. This dependence is known as Lambertian
illumination.

Because of refraction at the air-polymer boundary 9,
the range of angles over which the light rays propagate
within the polymer layer 7 is reduced, as shown in the
35   polar plot of Figure 5.

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As shown in Figure 6, the rays then strike the
diffractive grating 5 on the surface of the facets 2 at a
range of angles and a proportion of the rays are
diffracted. For the sake of reducing the complexity of
5   this description, it is assumed that (i) where diffraction
is possible, all of the light is diffracted, and (ii) where
diffraction is not possible, the light is absorbed or
transmitted by the diffractive grating 5 as described
above. It is to be understood, however, that in practice
10   the diffraction efficiency will vary with wavelength and
angle.

Some of the light that is diffracted by the
diffraction grating 5 on a particular facet 2 is shadowed
by the neighbouring facet 2 and does not leave the
15   diffractive structure 100. The polar plot of Figure 7
shows the distribution of the diffracted rays from one
facet 2 of the diffractive structure 100 for three
different wavelengths. These wavelengths correspond to the
peaks of the visual colour response. The solid line
20   represents blue light, the dotted line represents green
light and the dashed line represents red light.

As the rays leave the polymer layer 7, they are again
refracted at the air-polymer boundary 9. Figure 8 shows
the distribution of rays that leave the diffractive
25   structure 100 having been diffracted by one facet 2.

The light rays leaving the one facet 2 can be added to
the rays from the neighbouring facet 2 to produce a plot on
a standard CIE (Commission International de l'Eclairage)
colour chart showing how the perceived colour varies with
30   viewing angle. The chart is reproduced in Figure 9. Over
an 80° range of viewing angle (plus or minus 40° from the
normal to the polymer layer surface 9), there is very
little variation in perceived colour. In this case, the
diffractive structure 100 produces a yellow colour under
35   diffuse illumination. Different colours may be produced by
altering the facet angles (i.e. the angle of a facet 2 to

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the polymer layer surface 9) and the period d of the
diffraction grating 5.

Thus, the present invention provides a colour
diffractive structure 100 which retains a saturated colour

5   when viewed in diffuse lighting over a wide range of
viewing angles.

The structure 100 can be mastered by conventional
ruling techniques over a large area, and can be formed in a
continuous polymer film by a single step embossing process

10   similar to that used in the production of holograms.

The colour primarily depends on the facet angles and
the pitch of the diffraction grating, neither of which
change significantly during wear. The diffractive
structure 100 is therefore ideal for production of large

15   volumes of material. The diffractive structure 100 has
particular application in security films on, for example,
credit or debit cards where very many substantially
identical diffractive structures 100 are required.

An embodiment of the present invention has been

20   described with particular reference to the example
illustrated. However, it will be appreciated that
variations and modifications may be made to the example
described within the scope of the present invention.

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CLAIMS

1.   A diffractive structure, the structure (100)
comprising:
5   a substantially planar substrate (1); and,
         a set of facets (2) formed in or on said substrate
(1), the plane or planes in which the facets (2) lie being
arranged at a non-zero angle to the plane of the substrate
(1);
10   the facets (2) having a diffraction grating (5) formed
thereon.

2.   A structure according to claim 1, wherein the facets
(2) lie in substantially the same plane.
15

3.   A structure according to claim 1, wherein the facets
(2) lie in substantially parallel planes.

4.   A structure according to claim 3, wherein the facets
20   (2) lie in substantially regularly spaced parallel planes.

5.   A structure according to any of claims 1 to 4, further
comprising a second set of facets (2) which lie
substantially in a second plane or planes which are at a
25 . finite angle to both the first set of facets (2) and the
plane of the substrate (1) such that the first and second
set of facets substantially oppose each other.

6.   A diffractive structure, the structure (100)
30   comprising:
         a first row of facets (2) which lie in substantially
the same first plane; and,
         a second row of facets (2) which lie in substantially
the same second plane, the second plane being at an angle
35   between 0° and 180° to the first plane such that the first

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row of facets (2) and the second row of facets (2) oppose
each other;

　　　each facet (2) having formed thereon a diffraction
grating (5).

5

7.　　A structure according to claim 6, wherein the first
facets (2) and the second facets (2) are substantially
parallel.

10　　8.　　A structure according to claim 6 or claim 7,
comprising further rows of facets (2) which lie in
respective planes substantially orthogonal to the first
plane.

15　　9.　　A structure according to any of claims 6 to 8,
comprising further rows of facets (2) which lie in
respective planes substantially parallel to the first
plane.

20　　10.　　A structure according to any of claims 6 to 9, wherein
the facets (2) are formed in or on a substantially planar
substrate (1), the planes in which the facets (2) lie being
at an angle between 0° and 180° to the plane of the
substrate.

25

11.　　A structure according to any of claims 1 to 10,
wherein the facets (2) are provided by the faces of square-
base pyramids (3).

30　　12.　　A structure according to any of claims 1 to 10,
wherein the facets (2) are provided by the faces of cubes.

13.　　A structure according to any of claims 1 to 10,
wherein the facets (2) are provided by a corner cube
35　　structure.

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14. A structure according to any of claims 1 to 10,
wherein the facets (2) are provided by the faces of
tetrahedra.

5   15. A structure according to any of claims 1 to 10,
wherein the tetrahedra are regular tetrahedra.

16. A structure according to any of claims 1 to 15,
wherein the diffraction grating (5) is provided by series
10 of grooves (6) across the facets (2).

17. A structure according to any of claims 1 to 15,
wherein the diffraction grating (5) is provided by a
crossed grating on the facets (2).

15

18. A structure according to any of claims 1 to 15,
wherein the diffraction grating (5) is provided by an array
of pits and peaks on the facets (2).

20 19. A structure according to any of claims 1 to 18,
wherein the typical periodicity of the diffraction grating
(5) is less than one wavelength of visible light.

20. A structure according to any of claims 1 to 19,
25 wherein the volume between the facets (2) is filled with a
transparent material (7).

21. A structure according to any of claims 1 to 20,
wherein the facets (2) are formed of a polymeric material
30 coated with a layer of metal.

22. A structure according to claim 21, wherein the metal
layer is discontinuous over the diffraction grating (5) on
the facets (2).

35

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23.   A security film including a diffractive structure
(100) according to any of claims 1 to 22.

24.   A method of manufacturing a diffractive structure
5   according to any of claims 1 to 23, the method comprising
the steps of:
       (A) producing a mould by machining a substrate with
repeated passes of a cutting tool, the tool cutting the
substrate deeper on each pass of the tool thereby to
10   produce a cut face having machining lines;
       (B) repeating step (A) to cut a further similar lined
face opposite said first face thereby to produce a groove
having machining lines on each opposed face;
       (C) producing a master from said mould; and,
15   (D) producing the diffractive structure from said
master, each facet having formed thereon a diffraction
grating corresponding to the machining lines of the grooves
in the mould.

20   25.   A method according to claim 24, wherein further lined
grooves parallel to the first lined groove are cut by
repeating steps (A) and (B).

26.   A method according to claim 24 or claim 25, wherein
25   further lined grooves orthogonal to the first lined groove
are cut by repeating steps (A) and (B).

27.   A method according to claim 24, wherein further lined
grooves parallel to the first lined groove are
30   simultaneously cut with the first lined groove by a ganged
series of cutting tools.

28.   A method according to claim 24 or claim 27, wherein
further lined grooves orthogonal to the first lined groove
35   are simultaneously cut by a ganged series of cutting tools.

29. A method of manufacturing a diffractive structure according to any of claims 1 to 23, the method comprising the steps of:

(A) producing a mould by anisotropic etching in a
5   silicon substrate to produce a plurality of facets on the mould;

(B) coating the mould with a resist layer;

(C) writing the fine structure of the diffraction grating directly into the resist with an electron beam or
10   an ion beam;

(D) producing a master from said mould; and,

(E) producing the diffractive structure from said master.

15   30. A method according to any of claims 24 to 29, wherein the master is produced by electroforming the mould.

31. A method according to any of claims 24 to 30, wherein the diffractive structure is produced by thermoforming the
20   master.

32. A method according to claim 31, further comprising the step of coating the facets of the diffractive structure with a metal layer.
25

33. A method according to claim 32, wherein the metal layer is discontinuous over the diffraction grating on the facets.
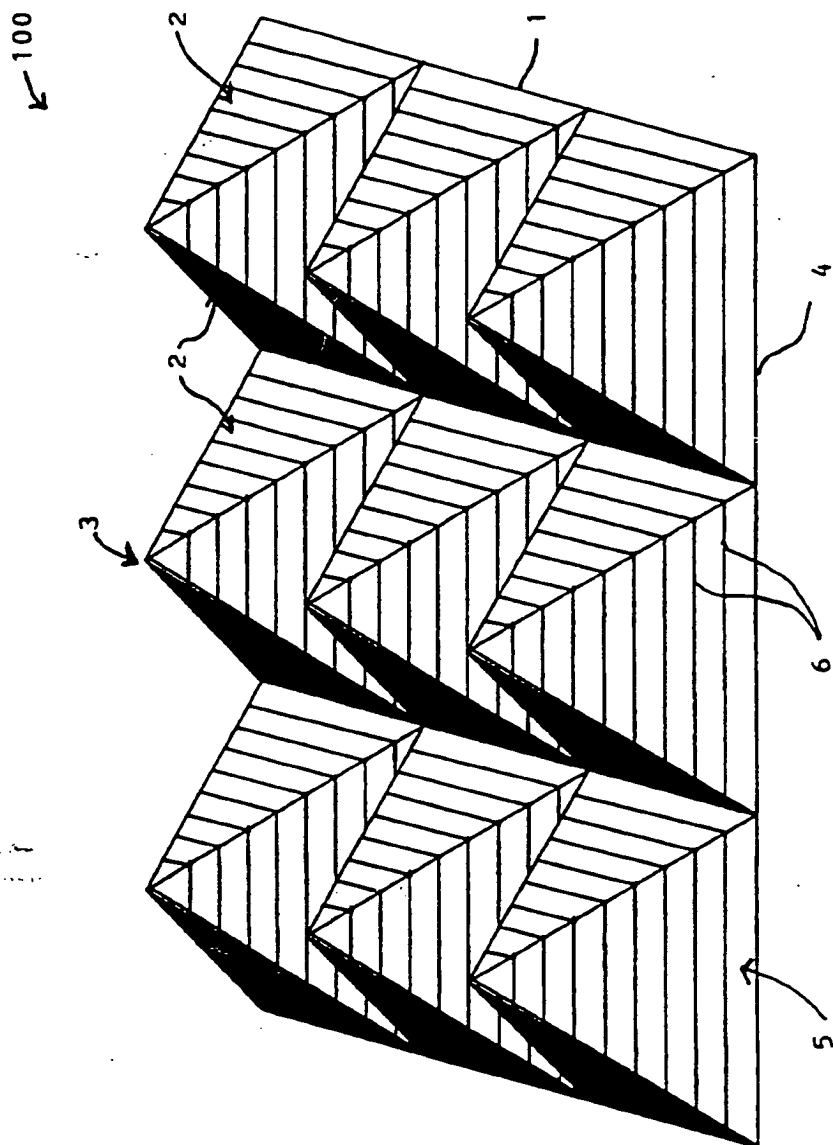
Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

$$\text{Intensity}_{i,8}$$

$$\frac{2 \cdot \pi \cdot \text{Angle\_refraction}_i}{360}$$
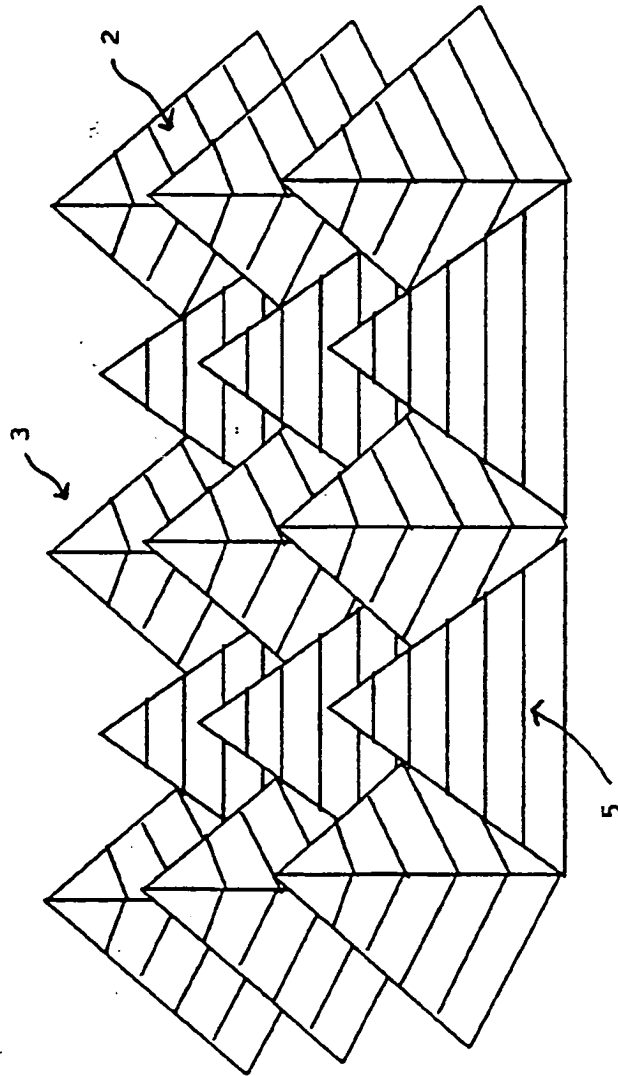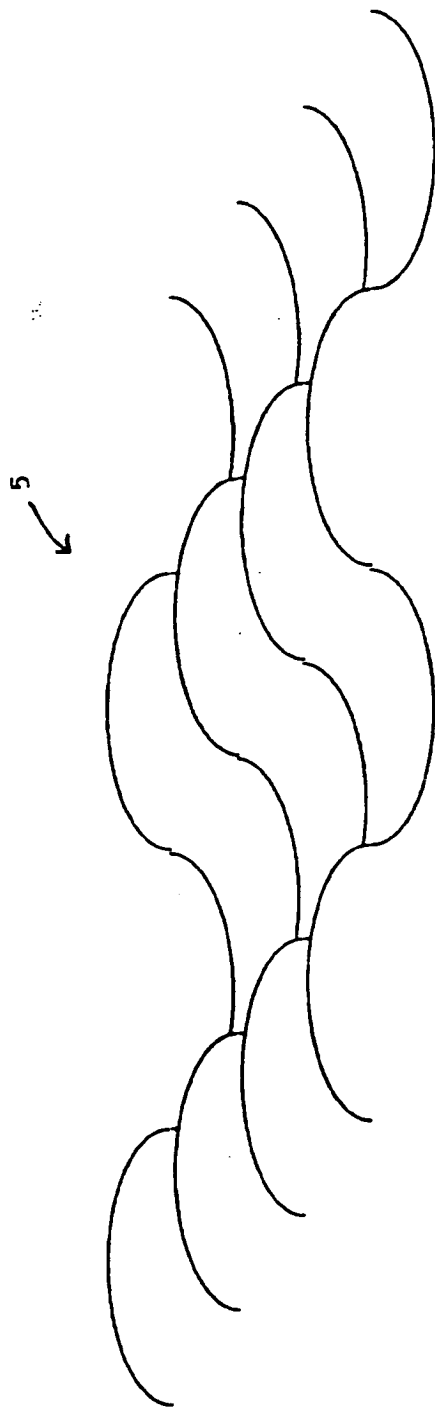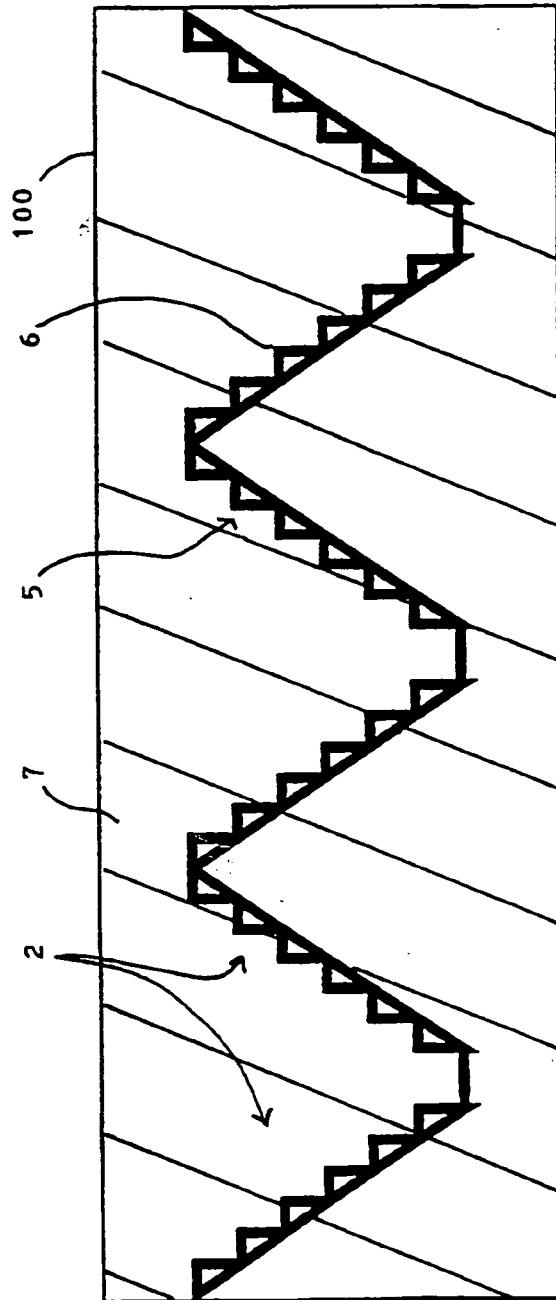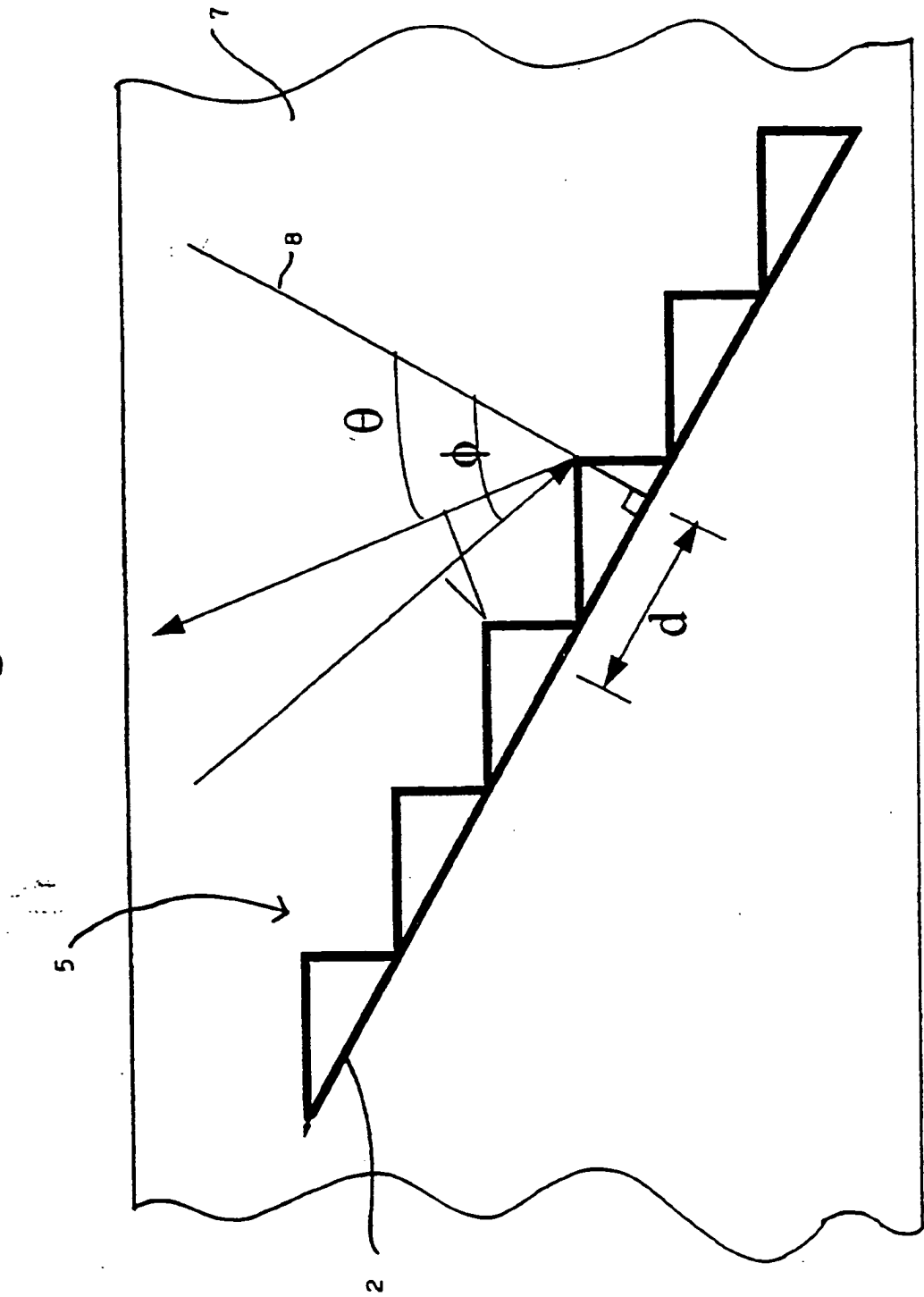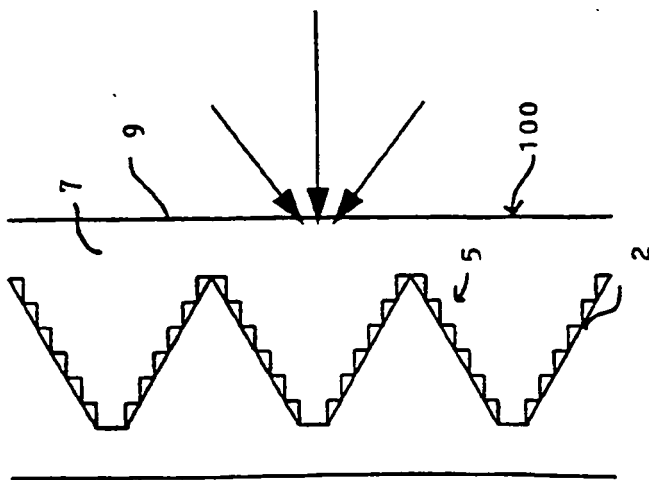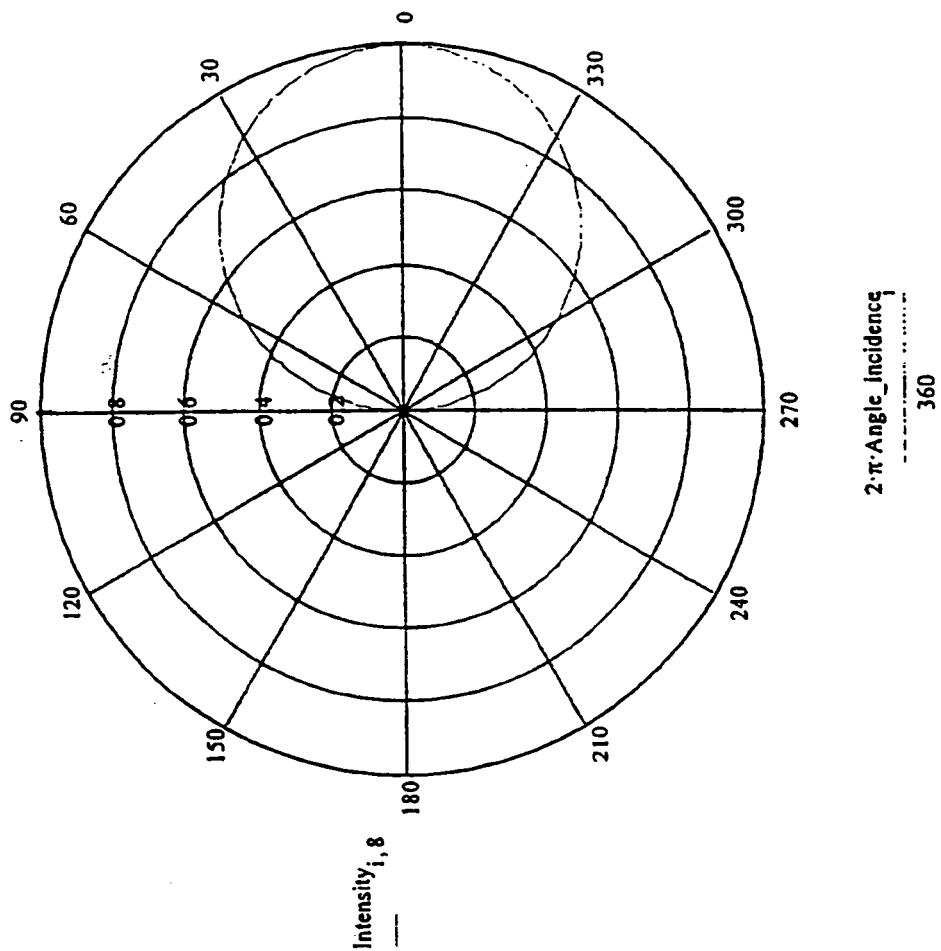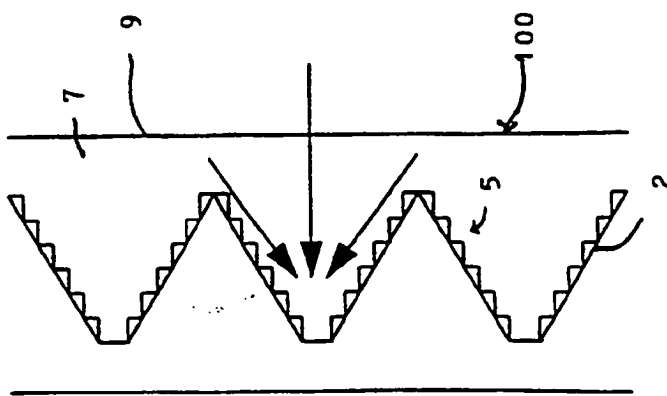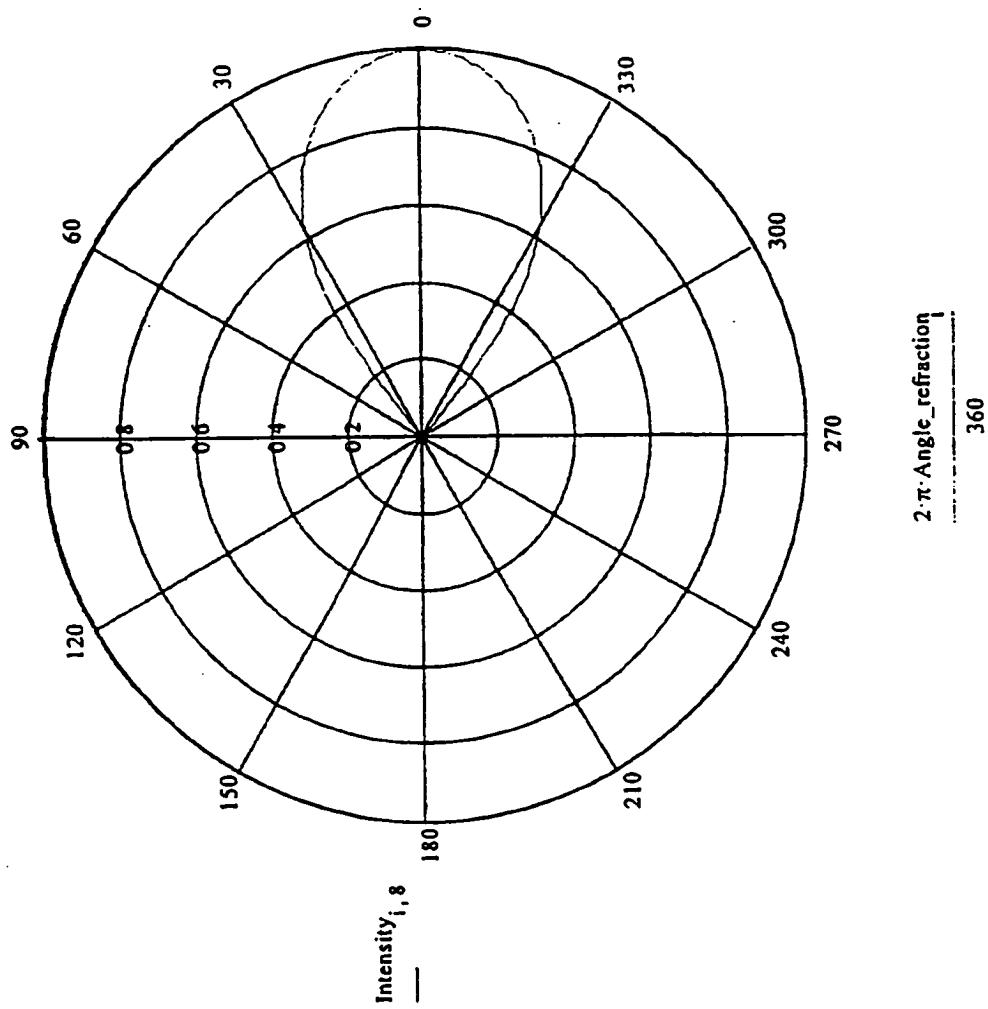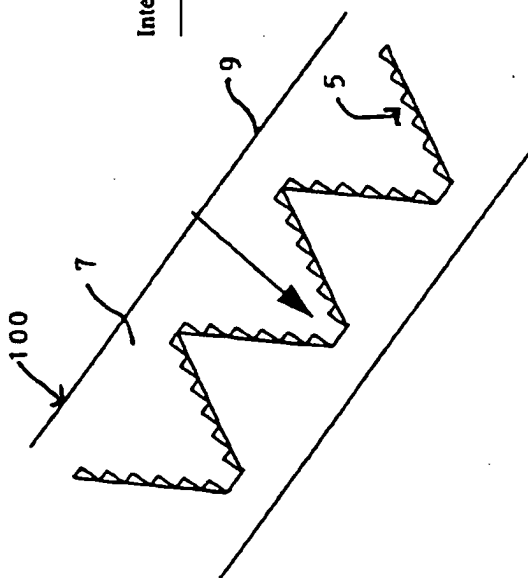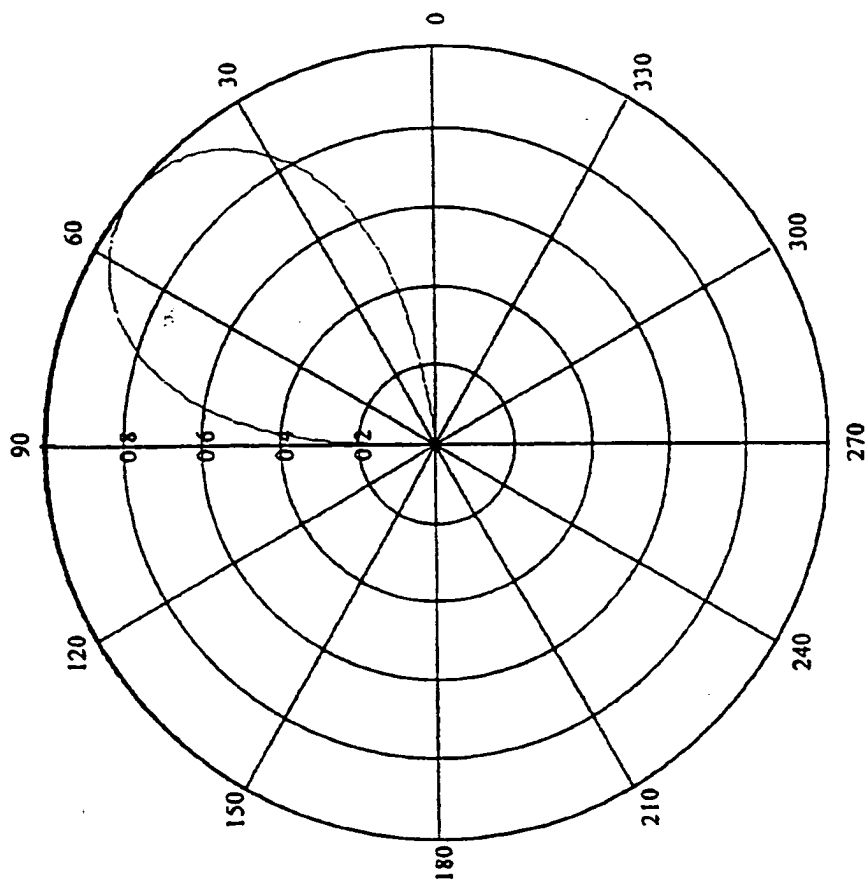
Figure 8

2·π·Angle_incidence_on_grating
─────────────────────────────
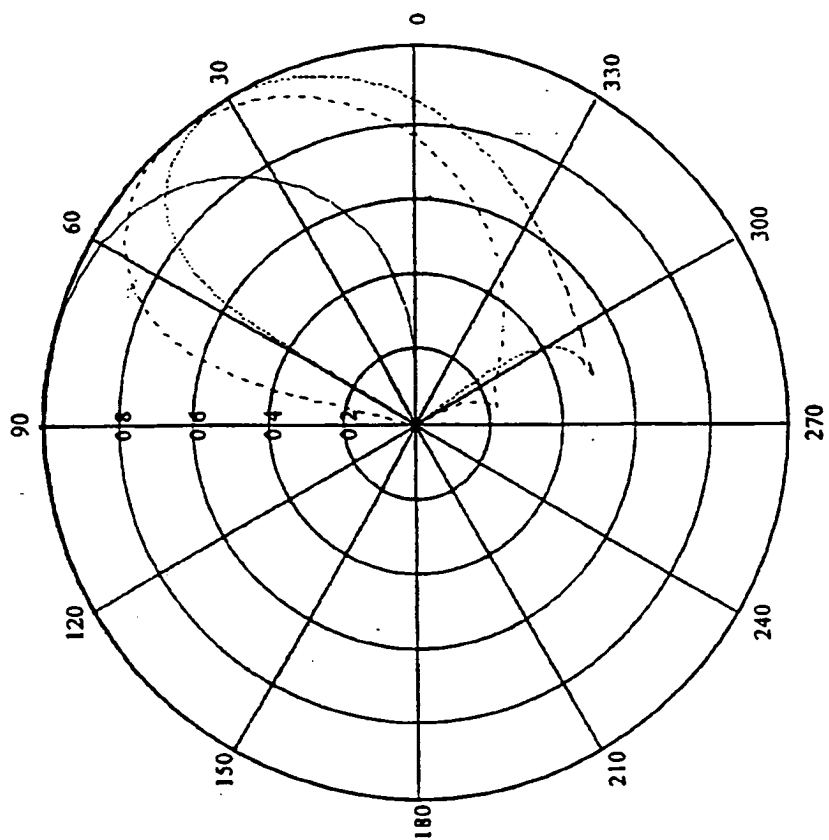   360
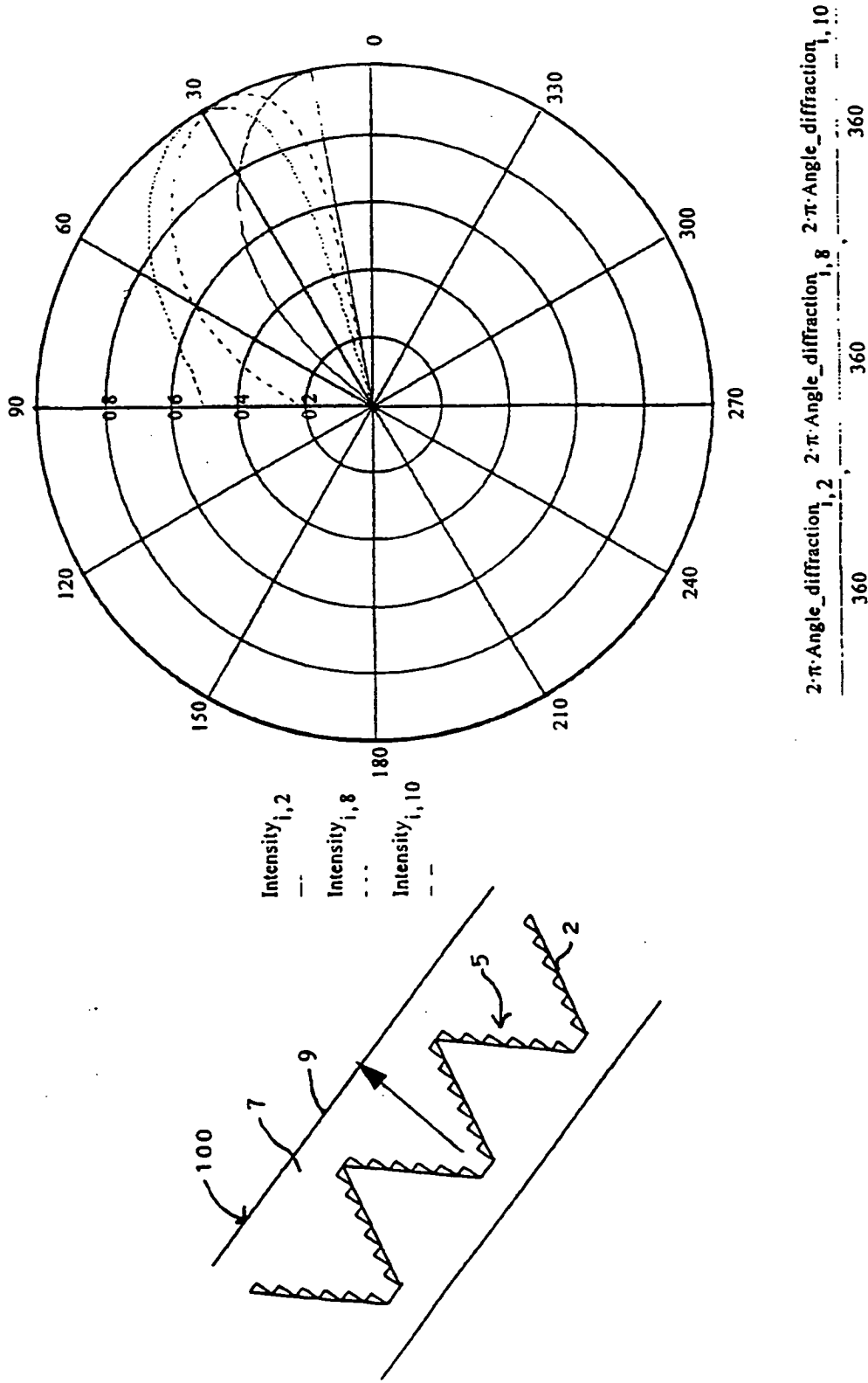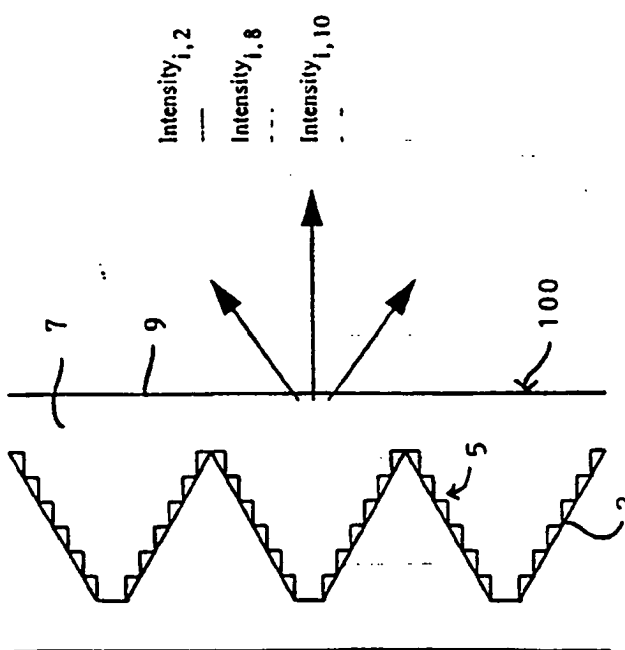
Intensity_i, 8
─────────

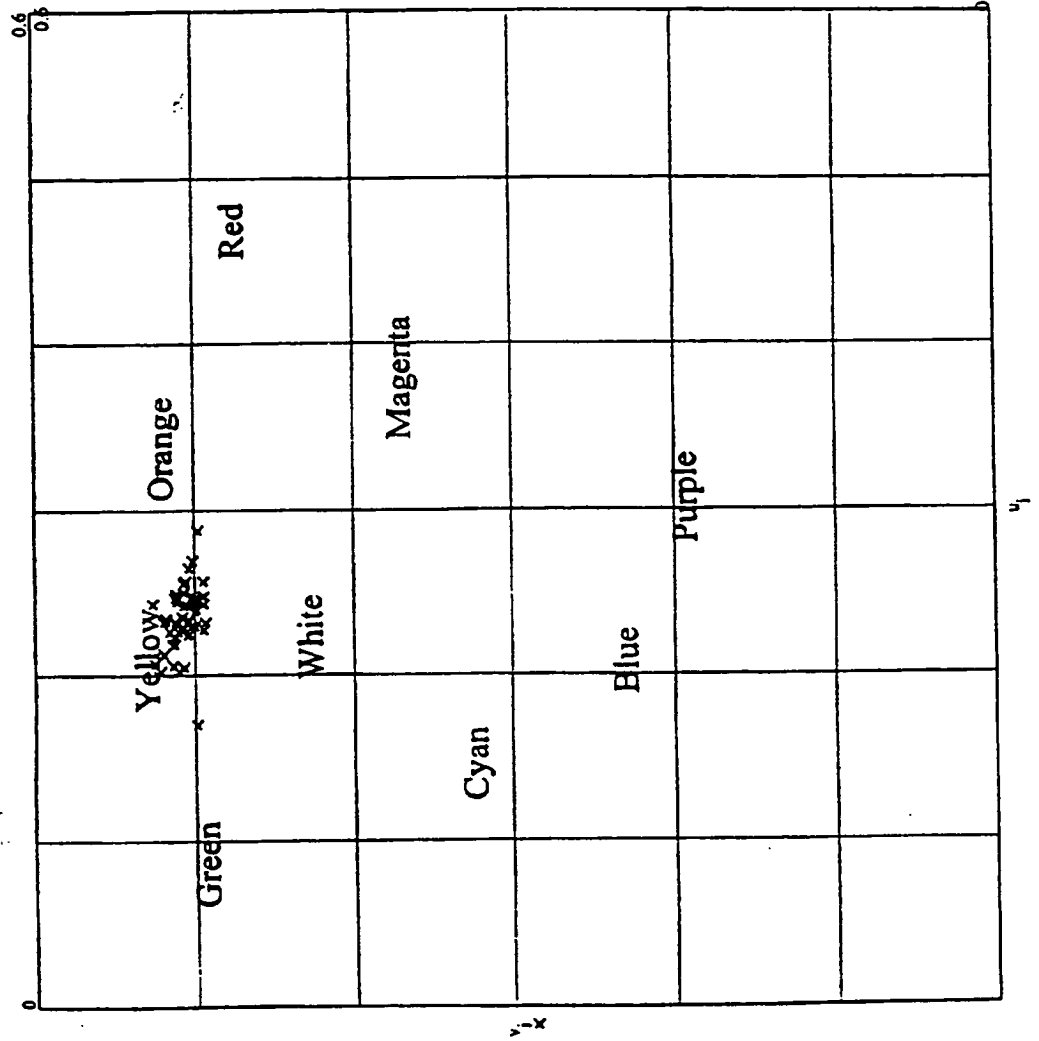# Figure 9

Figure 10

$$\frac{2 \cdot \pi}{360} \cdot \text{Angle\_exit}_{i,2}, \frac{2 \cdot \pi}{360} \cdot \text{Angle\_exit}_{i,8}, \frac{2 \cdot \pi}{360} \cdot \text{Angle\_exit}_{i,10}$$

Intensity$_{i,2}$ ———

Intensity$_{i,8}$ — · —

Intensity$_{i,10}$ · · · ·

Figure 11

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G02B5/18   B42D15/10   G06K19/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G02B   B42D   G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 057 271 A (LANDIS & GYR AG) 11 August 1982	1,3,5, 20,23
A	see page 20, line 8 - line 15	6,7,9, 10,16, 18,21, 24,29
	see figure 32	
P,X	EP 0 715 189 A (FRANCE TELECOM) 5 June 1996	1,3-5,16
P,A	see the whole document	6,7,9, 10,18,21
A	DE 42 25 007 A (MUELLER HELMUT FRANK OTTOMAR P) 3 February 1994 see the whole document	1,6,11
	-/--	

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 March 1997	2 6. 03. 97

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JOURNAL OF PHYSICS E SCIENTIFIC INSTRUMENTS., vol. 3, no. 12, December 1970, BRISTOL GB, pages 953-961, XP002027792 LOEWEN E G: "Diffraction Gratings for Spectroscopy" see the whole document ---	24
A	JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART B, vol. 5, no. 1, January 1987, NEW YORK US, pages 33-36, XP002027793 TERUHIRO SHIONO ET AL: "Computer controlled electron beam writing system for thin film micro optics" see the whole document ---	29
A	SENSORS AND ACTUATORS A, vol. A51, no. 1, 1 October 1995, pages 77-80, XP000545377 KLUMPP A ET AL: "ANISOTROPIC ETCHING FOR OPTICAL GRATINGS" see the whole document -----	29

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DE 4225007 A	03-02-94	NONE	